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A one health approach to reducing schistosomiasis transmission in Lake Malawi

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Abstract

Objective: To review what we know about urinary schistosomiasis in Lake Malawi and summarize our attempts to use fishes as a biological control of the intermediate hosts.

Conclusions: A One Health approach must be employed to effectively control urinary schistosomiasis in Lake Malawi. Health clinics must be supplied with praziquantel for distribution. Education centers must emphasize the need for sanitation and clearly state precautions (e.g., avoid swimming between 1000-1500). Additionally, the importance of snail-eating fishes to control the intermediate hosts must be emphasized. If biological controls are to be implemented, alternate food sources (agriculture, aquaculture) must be made available. A true One Health approach must be utilized to effectively control the transmission of schistosomiasis along the lake shores of Lake Malawi.

Introduction

Zoonosis are diseases that can be naturally transmitted between non-human animals and humans and include bacteria, viruses, or parasites (World Health Organization, www.who.int/topics/zoonoses/en/). Conversely, reverse zoonosis or zooanthroponosis is when humans transmit diseases to non-human animals [1]. The transmission of infections among species is intensified by the convergence of humans, other animals, and the environment [2]. Of the 1,461 diseases now recognized in humans, approximately 60% are multi-host pathogens and over the past 30 years 75% of the emerging human infectious diseases were zoonotic [2]. Gibbs [3] listed six interconnected parameters that have increased the rate of emerging diseases including: global trading and tourism; speed of mass transportation; exposure to new pathogens through ecosystem disruption; intensification and monoculture in farming; sophistication of food processing, and evolutionary pressures through overpopulation.

Trematode species have complex life cycles alternating between a final host where sexual reproduction occurs and a first intermediate host where asexual multiplication transpires. Adult trematodes in the final hosts (humans and possibly reservoir hosts) deposit eggs which exit the host via feces or urine. For some species, eggs that reach freshwater hatch to a miracidium that subsequently infect a snail, while eggs of other species are eaten by an appropriate snail inside which, they will hatch and continue their development (e.g., eggs of *Clonorchis sinensis* and *Opisthorchis* spp. as well as intestinal trematodes, i.e., Heterophyidae). Through asexual multiplication, a new infective stage develops inside the snail and upon release from the snail, cercariae can either infect the final host directly through skin penetration (e.g., *Schistosoma* spp. causing schistosomiasis [4]; or they infect its second intermediate host such as fish where they develop into metacercariae (e.g., fish-borne zoonotic trematodes causing clonorchiasis or opisthorchiasis and intestinal flukes causing heterophyasis and crustacean borne trematodes causing paragonimiasis [5,6]); while for other species, cercariae, the larval stage produced in snail host upon release encyst on aquatic plants (e.g., liver flukes such as *Fasciola* spp. causing fascioliasis in domestic animals and sometimes humans [7]). Final hosts become infected consuming metacercariae with fish, crustaceans, or aquatic plants.

Certainly, the control of infections by trematodes, which are transmitted from non-human animals (i.e., snails, the first intermediate host or for some species from a second intermediate host) to humans must employ a One Health [8,9] approach such that the parasite is attacked at all stages of its life cycle.

Trematode caused diseases are serious problems of both public health and veterinary importance. Although infections by some of these trematodes in the final hosts can be effectively reduced through medical treatment, reinfection appears very quickly [10-13]. Thus, it is necessary to take a holistic approach to control.

Treatment of infections by trematodes involves the understanding of the multiple host species, environmental control, and behavior modifications and includes several scenarios.

1. Interventions to reduce the contamination of water bodies with trematode eggs. Probably, the most effective means of reducing egg contamination would be medical treatment of the final hosts (humans and possibly reservoir hosts). This could also involve

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sanitary improvements to reduce contamination of waterbodies with human feces or urine; prevention of reservoir hosts to have access to the water bodies e.g. dogs, cats and wild birds for some of the fish borne zoonotic trematodes. In aquaculture, avoiding the use of manure from domestic animals could be an important way of reducing egg contamination as could prevention of rain run-off into the ponds [13].

2. Reduce the chance of eggs or miracidia infecting the first intermediate host (freshwater snail) and this could be attempted through snail control using either habitat modification, chemical control, or biological control. Obviously, what is feasible depends on the type of habitat.

3. Reducing the likelihood that cercariae or metacercariae infecting a final host. Snail control would reduce cercariae production in transmission sites. For schistosomiasis this could be through reducing water contact through supply of safe water supply. For fish-borne zoonotic trematodes (FZT) this would be attempted through behavioral changes, e.g., not eating raw fish, cooking fish remains before feeding it to animals (pigs, dogs and cats). Preventing these animals from getting to the ponds.

We have been studying human urinary schistosomiasis in Lake Malawi for more than two decades [14-26]. The purpose of this paper is to review what we know about human schistosomiasis in Lake Malawi and document our attempts to use biological controls to reduce its prevalence.

Schistosomiasis in lake Malawi

Schistosomiasis is one of a few macro parasitic diseases with aquatic intermediate hosts that fish have been used as biological control agents (see Table 1 in Stauffer et al. [14] for a list of parasitic diseases that may be susceptible to control via fish predation). The prevalence of both urinary and intestinal human schistosomes has been documented in the catchment basin of Lake Malawi for close to 100 years [27-29]. Historically the open shorelines of Lake Malawi were free from human urinary schistosomes [15,21]. The only known intermediate host of urinary schistosomes, *Schistosoma haematobium*, in Lake Malawi was *Bulinus globosus*, which is found in inland, slow-moving waters, and limited areas within the lake that are protected [15]. Beginning in the mid-1980s, however, infection of tourists and researchers' swimming in the open waters of Lake Malawi indicated that transmission was occurring in the open waters [14,30-34]. Open water transmission of schistosomiasis was further supported when the prevalence of infection in school-aged children at Chembe Village jumped from 36% in 1978 to to 87.4% in 2003 [17]. At that time, we speculated that overfishing of molluscivorous fishes (i.e., *Mylochromis* spp., *T. placodon*) enabled *B. globosus* to survive in the open waters of the lake. We revised our conjecture when Madsen et al. [35] discovered an endemic snail, *Bulinus nyassanus*, infected with human schistosomes in the shallow waters of Nankumba Peninsula in southern Lake Malawi.

In a series of experiments, when *B. nyassanus* were exposed to eggs retrieved from children from Chembe Village, one snail was infected [19]. We collected 24,775 *B. nyassanus* from Chembe Village and only found 87 (0.4%) infected. Overall, the prevalence of infection of *B. nyassanus* by *S. haematobium* ranged from 0-2% at 10 sites along the shore line of Chembe Village (Nankumba Peninsula) [14]. Although rare, clearly *S. haematobium* can utilize both *B. globosus* and *B. nyassanus* as intermediate hosts. No infected *B. nyassanus* have been found in the northern portions of Lake Malawi. Stauffer et al. [18] postulated that a strain of *S. haematobium* from other parts of Africa was introduced into the Cape Maclear region by tourists, hybridized with the local strain, and via introgression produced a variety that could use both *B. globosus* and *B. nyassanus* as intermediate hosts.

From 2003-2007, the overall prevalence of urinary schistosomiasis in school-aged children varied between 15.3-57.1% in inland villages in Malawi to 56.2-94.0% in lake shore communities [21]. In 2003, Stauffer et al. [14] initiated a lake-wide survey of snail-eating fishes, intermediate hosts of schistosomes, and prevalence of infection in school-aged children. They determined 1) the density of snail-eating fishes (e.g., *Trematocranus placodon*) was lower than found in 1978; 2) peak densities of snail-eating fishes shifted to deeper waters than found in 1980; 3) increased prevalence of the disease was coincident with a decrease in density of molluscivorous fishes. Stauffer et al. [14] further concluded that the high incidence of schistosomes in southern Lake Malawi was linked to the schistosome using two intermediate hosts.

Intervention

Lerner et al. [9] postulated that the concept of health be approached on the individual level, the group or population level, and the ecosystem level. We postulate that only with a One Health program can the prevalence of urinary schistosomiasis be effectively controlled within Malawi. Along the shores of Lake Malawi there are several entities that provide treatment for schistosomiasis. Unfortunately, reinfection occurs extremely rapidly. Serological examination of circulating anodic antigens of school children treated for schistosomiasis demonstrated that approximately 70% of the children became re-infected after one year. We have provided extension publications to explain the disease that are published in both English and Chechewa, distributed them throughout the villages, and posted them on the web [36]. We have worked extensively with the Chief of Chembe Village, the Village Development Committee, and the Beach Committee. The people in the village understand the debilitating effects of the disease, how the disease is transmitted, and the fact that overfishing of the snail-eating fishes will increase transmission. They must ask themselves at least two basic questions – "Do I maybe contract a schistosome infection in the future?" or "Do my family and I go to bed hungry?" Thus, we must be able to provide alternate food sources, if fishing is restricted to certain areas and during certain times of the year.

The fish ban (i.e., no-seine-net fishing within 100 m from the shore line) initiated by personnel from the Lake Malawi National Park, was initially met with enthusiasm, but we now have evidence that it is no longer enforced. Although the purpose of the ban was to protect the rock-dwelling small fishes endemic to the park, it also protected the breeding areas of the snail-eating fishes. During the time we were present, we did observe a decrease in prevalence of infection among school-aged children that was associated with an increase in the number of snail-eating fishes. This decrease was probably caused by an interaction between increased numbers of fishes, a reduction in intermediate hosts, and extensive treatment in the village. We proposed a modification of the existing fish ban that would prohibit fishing within 100 m of the shoreline during Jan-Feb and Aug-Sept, when the snail-eating fishes were spawning. During other times of the year, we suggested that the villagers do not line their seines with mosquito nets, thus allowing juvenile and small fishes to escape. If we desire such a fish ban to be successful, however then we must create alternative sources of animal protein during these times; thereby reducing the dependence on fishes harvested from Lake Malawi.

Concluding remarks

In Lake Malawi, transmission of schistosomiasis has been established within the last 20 years along open shorelines with sand or gravel sediment in the southern part of the lake [14,34]. We have evidence that suggests that this is the result of over fishing resulting in a significant decline in densities of molluscivorous fishes; especially seine-net fishing with very fine meshed nets directly from the shore is detrimental to fish populations [17]. Transmission, however, also occurs in the many streams and backwaters which constitute excellent habitats for *Bulinus globosus* [20]. We intend to address management of these inland waters for aquaculture to reduce fishing pressure in the near shore area of the lake and to control transmission in inland habitats close to the lake.

One solution may be the integrated environmental management required for aquaculture. If properly implemented, such a program could greatly reduce transmission of vector borne diseases (primarily malaria and schistosomiasis). Our research group has many years of experience from working on the Nankumba Peninsula (Mangochi District) through a two-year schistosomiasis control project funded by the Danish International Development Assistance and through an NIH/NSF funded project (5 years) on the relationship between schistosomiasis, snails, and fishes. Some of our ideas for future research on control of schistosomiasis were specifically developed to reduce fishing in the lake primarily through the aforementioned fish ban or structures that physically prevent seine net fishing from the shore and aquaculture in inland habitats. The use of the structures to inhibit fishing was proposed to prevent fishermen from other villages to fish along the shores of Chembe Village. When the fishermen from Chembe Village stopped fishing in the near-shore areas, the number of fishes increased over a five-year period. Subsequently, fishermen from other villages were attracted to Chembe Village and would fish in these near-shore areas. The supply of fish per capita has steadily fallen due to high population growth against declining fish production and this is a real threat to food and nutrition security in Malawi. In 1976, per capita annual fish supply was 12.9 kg. This had fallen to 7.9 kg in the 1990s and then decreased further to 3.6 kg in 2001 (FAO -- http://www.fao.org/fishery/facp/MWI/en#CountrySector-Overview). Therefore, efforts to supplement production from the natural water bodies would not only increase fish supply but also improve nutrition standards of rural households in the Mangochi District.

People living in the African Region face a heavy and wide-ranging burden of disease, which takes its toll on social and economic development and shortens their life expectancy [37]. Health services in these countries are often not able to address adequately this severe burden of disease. Just as health can drive economic growth, ill-health can push people into poverty and make it very difficult for them to escape the poverty trap [37]. Although poverty can result from ill-health, we believe that poverty alleviation through creation of job opportunities and improved food supply could improve health status, i.e. not only through reduced transmission risk of diseases but also through sensation of self-reliance, job satisfaction, and increased standard of living. Poverty traps are observed in societies too impoverished to generate an economic surplus that can be reinvested to break out of the trap [38]. When societies have no income beyond what is needed for subsistence, infrastructure cannot be built, schools and clinics are insufficient and understaffed, and savings that go towards private enterprise are almost entirely absent [38]. Empowering women is crucial to lifting countries out of poverty and improving health in the Region [37]. Clearly, there is a great need to increase food production in the region. Agriculture will remain a key economic sector for developing countries and agricultural productivity has to increase dramatically, and this requires a multifaceted approach [38]. One of the problems in the health care system is that they are not locally available, and that treatment often is delayed due to costs of transport to higher-level health facilities and thus may be prohibitive. Strengthening local community health centers would result in more prompt health service seeking behavior and if we can improve people's financial status through creation of job opportunities, health service seeking would also be improved when referral to higher level centers is required, i.e., it is financially possible and not seeking treatment would mean loss of income.

The above must also be coupled with an increase in sanitation throughout the communities along the lake shore. Education of the life cycle of the schistosomes must be taught to both children and adults. Simple behavioral changes such as not entering the water between 1000 and 1500 can be implemented. Health clinics must be established and praziquantel made available to all those who test positive for infection. There truly must be a One Health approach.

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